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SELF-CALIBRATED NON-CONTACT CAPACITIVE TYPE LEVEL SENSOR FOR LIQUID AT DIFFERENT TEMPERATURES

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ABSTRACT

A novel non-contact, fringe capacitance based sensor is proposed to measure the liquid level in process industries, to avoid the effects of hazardous liquids / chemicals. In practical situations, the sensors are required to be calibrated repetitively when the dielectric medium/dielectric constant changes owing to the fluctuations in the process/environmental parameters. This work deals with the design of low cost, non-contact, fringe capacitance-based sensor for monitoring multi threshold levels employing self-calibration feature. A sensor with Al electrodes is fabricated and interfaced with PLC-S200 through switching unit. The performance is evaluated with same liquid at four different temperatures which leads to significant changes in dielectric constants. The results indicate that the concept of fringe capacitance facilitates the feature of self-calibration. It is also observed that the PLC-S200 monitors the existing threshold level with lowest error varying from 0.408% FSO to 0.816% FSO.

Key words: Fringe capacitance, dielectric constant, self-calibration, threshold levels.

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1. INTRODUCTION

Liquid level in a container is an important variable to monitor and control in process industries associated with chemicals and hazardous liquids. Among many level sensing techniques, the concept of conventional capacitance is an extensively used method [1]. The inaccurate performance of contact type capacitive sensors owing to their reaction with

hazardous liquids and dependence on liquid properties demands additional compensation system. This situation leads to the design and development of non-contact type sensors. Most of the present techniques employed for non-contact type liquid-level monitoring are not appropriate to measure liquid level through a container [2-8]. The cost, maintenance, health and safety issues of optic sources and thin-film residues limit the usage of optical sensors and are fiber optic sensors respectively [2-5]. Erroneous response due to the impact of variations in liquid properties on the speed of sound in ultrasonic sensor [6] and the impact of variation in dielectric constant of the media on the parameters associated with the measurement process in case of RF, millimeter and micro wave-based sensors [7, 8] necessitate re-calibration which is costly and tedious process. Some of these drawbacks are overcome by non-contact type capacitive sensing techniques. A capacitive sensor reported in [9] addresses the impact of variation in temperature on the dielectric properties of air. Sensors designed in [10, 11] monitor the level of both conducting and non-conducting type of liquids in metallic or non-metallic storage tank while a technique proposed in [12] minimize the effect of parasitic capacitances and fringe capacitances. A Capacitive level sensor comprising planar electrode structure, monitors both conducting and non-conducting liquids [13]. The common issue in all these sensors is that the techniques adopted are the functions of dielectric constant of the respective medium. The variation in dielectric constant owing to the fluctuations in process/environmental parameters deteriorate the accuracy of measurements which is the major issue. Consequently, the existing sensors demand liquid specific calibration in repetitive manner which is an expensive process.

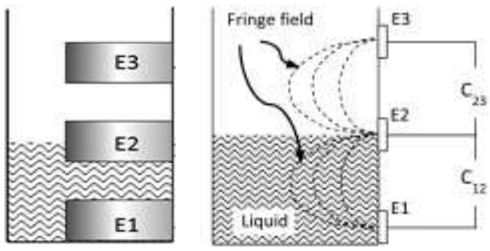
In the recent years, various capacitive methods comprising two sets of comb drive electrodes to avoid re-calibration are reported [14 & 15]. In these methods, the self-calibration is achieved by employing additional sensors which increases the cost and complexity of the system. Consequently, it is necessary to design a self-calibrated non-contact type liquid level sensor without using any additional sensor. The concept of fringe capacitance is most appropriate for non-contact measurements which offers one-side access to material under test [16, 17] and specifically for liquid [18].

The present work focusses on the development of a non-contact type, multi threshold level sensor based on the concept of fringe capacitance emphasizing on self-calibration.

2. THEORETICAL CONCEPT OF SENSOR

The fringe capacitance established between the edges of parallel electrodes offers ‘one side access’ to the media/object under sensing (measurand). Change in dielectric mass of the measurand present in the vicinity of electrodes interacts with the projected fringing field. It results in the corresponding change in the fringe capacitance. This implies that the concept of fringe capacitance can be employed for non-contact measurement which do not establish any physical contact between the electrodes and the sensing environment. A sensor based on this concept is realized by converting the parallel electrodes into planar electrodes. This change in geometry enhances the fringe capacitance.

A minimum of three electrodes are required to employ the concept of fringe capacitance [19 & 20]. The configuration of electrodes E1, E2 and E3, similar in geometry with uniform gap, mounted on the outer surface of the tank and their respective fringe capacitances C_{12} and C_{23} is as shown in the Fig.1. The established fringing field between E1, E2 and E2, E3 propagates through the tank wall and reaches the dielectric media (target liquid). The variation in the liquid level leads to the change in dielectric mass in the fringing field, influencing both C_{12} and C_{23}.



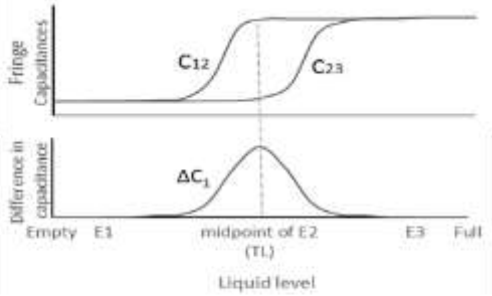


Figure.1. Concept of fringing capacitance **Figure 2.** Ideal characteristic curves of the

When the tank is empty, both fringe capacitances C_{12} and C_{23} are same and lowest due to very low dielectric constant of the air. As the liquid level rises, the first capacitance C_{12} is influenced while the C_{23} remains constant. The moment, the liquid reaches the mid-point of E2, the capacitance C_{12} attains its maximum value while the capacitance C_{23} remains at its minimum value. At this point, the difference between the capacitances will be maximum. For further rise in the liquid, the capacitance C_{23} is influenced while the C_{12} remains constant at its maximum value. When the liquid reaches E3, both C_{12} and C_{23} attain their maximum value which must be same in an ideal case. The difference in capacitance (ΔC) is given by (1),

$$C_{diff} = \Delta C_1 = C_{12} - C_{23} \tag{1}$$

Where,

C_{12} = Capacitance offered by E1and E2 electrodes

C_{23} = Capacitance offered by E2 and E3electrodes

ΔC_1 = Difference in capacitance offered by E1, E2 and E3 electrodes

The variations in fringe capacitances, C_{12} and C_{23}, and their difference ΔC_1 with liquid level using three electrodes, in ideal conditions, is as shown in Fig.2. The curve of ΔC_1 depicts that the maximum difference in capacitance (peak) corresponds to the liquid level at the mid-point of E2, referred as the threshold level (TL). Accordingly, the mode of measurement employed in the present work is the difference in capacitance to monitor the occurrence of its peak irrespective of its magnitude, corresponds to the threshold liquid level.

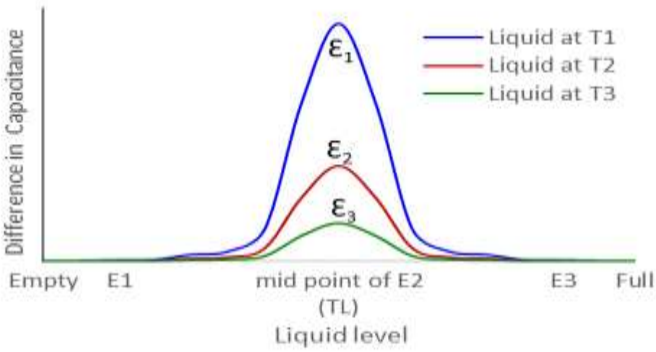


Figure 3. Variation of the difference in capacitance with liquid level

The existing contact and noncontact type capacitive sensors require repetitive calibration whenever there is a change in the dielectric constant of the target liquid. The change in dielectric constant may be due to variation in environmental / process parameters or a change in the dielectric media in the container itself. Figure 3 shows the variation of 'ΔC_1' for a liquid with different dielectric constants ε_1, ε_2 and ε_3 influenced by variation in process parameter (e.g. Temperature). It indicates that the magnitude of peaks differs with respect to

dielectric constant, however their occurrence exactly corresponds to the TL irrespective of varying dielectric constants of liquid. It implies that the mode of measurement is insensitive for any change in dielectric medium / dielectric constant, nevertheless determines the existing TL based on the occurrence of peaks, consequently ensures self-calibration.

3. DESIGN OF THE SENSOR

The realization of the proposed sensor unit is as depicted in Fig.1, comprising a minimum of three planar electrodes mounted on the outer surface of the tank wall. This configuration attains one-sided access to measurand and avoids the physical contact with the measurand. The individual fringe capacitances, C_{12F} and C_{23F} are provided by electrodes with the middle electrode being the reference.

For the proper functioning of the sensor, the criteria satisfied in the design process are

- The material of the tank is an insulator
- The geometry/profile of the storage tank must be uniform
- The shape of electrodes is rectangular and identical in dimensions and material
- The gap between the electrodes is uniform

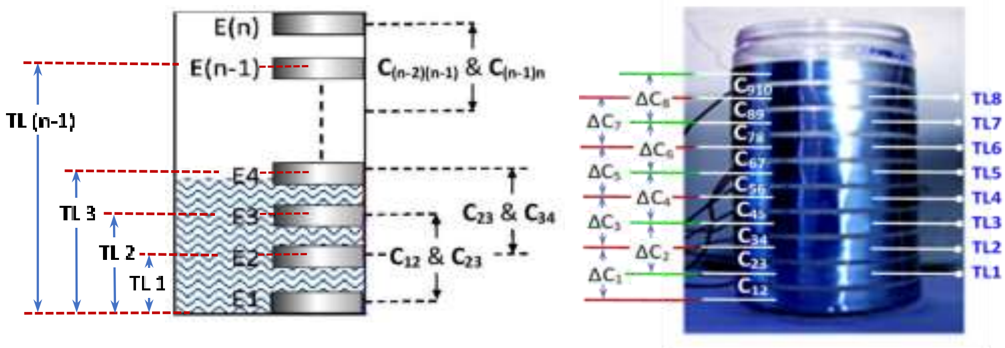
The first criterion ensures an electrical isolation between electrodes and physical isolation between the electrodes and measurand. The remaining criteria assurance the similar characteristic curves for individual fringe capacitances.

4. FABRICATIONOF MULTI THRESHOLD LEVEL SENSOR

4.1. Fabrication of the multi-threshold level sensor

The proposed sensor with the configuration of minimum of 3 electrodes can monitor only one specific level of liquid, termed as single threshold level. However, it is essential to monitor multi threshold levels of liquids in practical situations. An extension of this concept for multi threshold level monitoring is achieved with 'n' number of electrodes which produce the fringe capacitances C_{12}& C_{23} to $C_{(n-2)\,(n-1)}$ to $C_{(n-1)\,(n)}$ as indicated in Fig.4(a).

Consequently, ten identical Aluminium electrodes are incorporated to achieve multi threshold liquid level monitoring [19]. The electrodes of dimension, 200 mm length, 20 mm width and 1.7 mm thickness are mounted uniformly with a gap of 5 mm around the outer surface of the cylindrical container having 325 mm circumference, made up of Polyvinylchloride(PVC) material, as shown in Fig.4(b). Aluminium is preferred for the electrodes due to its less responsiveness for the atmospheric corrosion by forming thin layer of oxide known as passivation layer which protects the underlying metal from further corrosion [20].



(a) Schematic diagram (b) Fabricated model with Aluminium electrodes

Figure 4. Multi threshold level Capacitive sensor

4.2. Working of multi threshold level sensor

The theoretical aspect employed in this work implies that when the liquid level reaches the 1st threshold level (midpoint of E2), difference in fringe capacitance, ΔC_1 attains its maximum. The moment the liquid level reaches 2nd threshold level (midpoint of E3), ΔC_2 attains its maximum, while ΔC_1 reaches its minimum. This implies that only one peak ΔC occurs at any instance of time corresponding to the liquid threshold level at that instant. The same phenomenon holds good for any number of electrodes.

A Signal Conditioning Circuit (SCC) is designed to convert diminutive fringe capacitance output ΔC_1 to ΔC_8 (in the range of pico farads)in to an enhanced $\Delta V_1$to ΔV_8 for further monitoring using Siemens PLC – S200 [21].

The multi threshold level sensor with 10 electrodes demands many SCCs which increase the complexity of the experimental setup. To address this issue, a switching unit is designed using relays [19] which enables only three electrodes at an instance, limiting number of SCCs to one. The interconnection among the relays and SCC is executed to ground the middle electrode which is the reference for the measurement of fringe capacitances offered by any active three electrodes.

Siemens PLC–S200 is employed in this work to monitor and indicate the existing threshold level. Accordingly, the PLC is programmed to energize an appropriate pair of relays to communicate the fringe capacitance output of any three electrodes at an instance to SCC and to acquire the output of SCC. The Ladder logic approach is employed to determine the existing threshold level of liquid comprises of two phases. In this work, the electrodes in the vicinity of liquid - air interface point (liquid level), producing non-zero value of ΔC are stated as active electrodes for the clarity.

4.2.1. Phase I: Identification of active three electrodes

The first phase of the logic is to identify the active three electrodes corresponding to the existing liquid level. PLC energizes the relays for a period of preset time in sequence to communicate the capacitive output for instance ΔC_p of three consecutive electrodes at an instance start from the lowest. It acquires ΔV_p from SCC corresponding to ΔC_p and monitors for its non-zero value which is an indication of liquid level in the vicinity of active electrodes. Logically, ΔV_i (where i varies from 1 to p and [p + 1] to [n-2]) of any other three consecutive electrodes is zero since they are in the vicinity of either liquid or air.

4.2.2. Phase II: Determination of the threshold level

The criterion for monitoring the existing threshold level is that difference in voltage must be at its maximum possible value ($\Delta V_{p(max)}$). PLC is programmed to acquire and compare ΔV_p of two consecutive discrete levels of rising liquid in the vicinity of active three electrodes, recognized in Phase I. Realization of maximum difference in voltage output, $\Delta V_{p(max)}$ irrespective of its magnitude. is an indication of the presence of p^{th} threshold level (liquid-air interface is at the midpoint of $(p + 1)^{th}$ electrode). This technique enables the level measurement independent of dielectric constant of liquid.

4.3. Selection of material for tank to validate self-calibration feature

For the validation of self-calibration feature of the proposed sensor, it is necessary to consider one of the process / environmental parameters which affects the dielectric constant of water. As a result, for experimental purpose, water at different temperatures is considered which results in the change of dielectric constant according to the empirical formula [22] given in (2)

$$\varepsilon = 87.740 - 0.4008T + 9.398(10^{-4})\, T^2 - 1.410(10^{-6})\, T^3 \qquad (2)$$

Where,

ε = dielectric constant of water

T = Temperature of water

For this reason, it is necessary to consider a suitable material for the tank which can withstand the highest temperature of the target liquid. Accordingly, commercially available PVC-U (unplasticized) which is hard and rigid with an ultimate tensile stress, resistant to most chemicals and generally be used at temperatures up to 60°C is considered for the tank.

5. EXPERIMENTAL WORK

This section reveals the experimental work carried out to validate the extension of fringe capacitance concept for multi threshold level monitoring and to examine the feature of self-calibration under the circumstance of varying dielectric constant of liquid owing to the variation in temperature of liquid itself.

5.1. Performance evaluation of multi-threshold level sensor

The experimental verification of the proposed multi threshold level sensor with Al electrodes of dimensions (200 mm x 20 mm) is carried out with water as target liquid at room temperature (25^{o} C). With respect to rise in water in steps of 5 mm, the fringe capacitances C_{12} to $C_{9,10}$ are measured using MECO-954 RLC meter and the respective difference in capacitances ΔC_1 to ΔC_8 are computed. The response of sensor unit with SCC is interfaced to PLC-S200 by means of relay switching unit. and its performance in monitoring the various threshold levels of water is investigated.

5.2. Validation of self-calibration feature of sensor

An experimental work is carried out to validate this unique feature, continuing with water as target liquid in PVC-U container at four different temperatures say 30^{o}C, 40^{o}C, 50^{o}C and 60^{o}C which leads to noticeable variation in dielectric constant values of water. Table 1 depicts the temperature and the respective dielectric constant values of water. The data is acquired by measuring the resulting values of fringe capacitances C_{12} to $C_{9,10}$ for the uniform rise in water at each temperature, considered for the experiment. Also, the respective difference in capacitances ΔC_1 to ΔC_8 are computed.

Table 1. Liquids employed and their dielectricconstants [22]

Temp (^{o}C)	Dielectric constant
30	76,546
40	73.151
50	69.910
60	66.815

6. RESULTS AND DISCUSSIONS

The experimental verification of the proposed sensor is carried out with uniform rise in level of water in a PVC-U container. The analysis of the results of the fabricated sensor using the designed SCC and switching unit, is presented in two phases as follows:

- Performance evaluation of Multi threshold level sensor
- Validation of self-calibration of Multi-threshold level sensor

6.1. Performance evaluation of multi-threshold level sensor

The static characteristic curves comprising the experimental data about the variations in individual fringe capacitances C_{12} to $C_{9,10}$ and difference in capacitances ΔC_1 to ΔC_8 with respect to the rise in level of water are depicted in Fig. 5 respectively. Rise in water level is denoted as threshold levels TL_1 to TL_8 corresponding to the mid-point of electrodes E2 to E9 respectively is also indicated. It is comprehended from these experimental results that the variations in C_{12} to $C_{9,10}$ and ΔC_1 to ΔC_8 are similar and obey the ideal curve shown in Fig.2. It infers that the concept employed is applicable for any three successive electrodes. Also, the $\Delta C_{(max)}$ of any three active electrodes occurs closely at instant when the liquid reaches the respective threshold levels. It is observed that the maximum error of this sensor is about -3 mm or -1.22%FSO at TL6. The programmed PLC determines the occurrence of peak and indicates the existing threshold level successfully with a negligible error.

6.2. Validation of self-calibration of sensor at different temperatures

To validate the self-calibration feature of the proposed sensor, the range of temperature of water considered is from 30°C to 60°C in steps of 10°C. Figure 6(a) to 6(d) depicts the static characteristic curves comprising the experimental values of variations in C_{12} to $C_{9,10}$ and computed values of ΔC_1 toΔC_8 with respect to the rise in level of water at 30°C, 40°C, 50°C and 60°C respectively.

It is observed from these experimental results that,

- The variation of fringe capacitances from C_{12} to $C_{9,10}$ with respect to rise in level of water is similar and obey the ideal curve irrespective of the temperature of water. Figures 6(a) to 6(d) indicate that the magnitude of fringe capacitance varies from 24 to 180 pF, 24 to 171 pF, 22 to 160 pF and 21 to 158 pF with water at 30° C, 40° C, 50° C and 60° C respectively. The magnitude decreases owing to the decrease in dielectric constant of water with respect to the rise in its temperature as shown in Table 1.
- The variation of differential fringe capacitances from ΔC_1 to ΔC_8 is also similar and follows the ideal curve. The $\Delta C_{n(max)}$ of any three active electrodes occurs closely at instant when the liquid reaches the respective threshold levels. It is observed from the error analysis carried out that the measurement is accurate with an error ranging from + 0.408 % to + 0.816 % FSO.
- Magnitude of peaks of all ΔC curves are different from Fig.6 (a) to Fig.6 (d) due to change in temperature, hence change in dielectric constant of water. The criterion for the PLC to determine the threshold level is identifying the occurrence of peaks, irrespective of their magnitude. Thus, self-calibration is the reality.

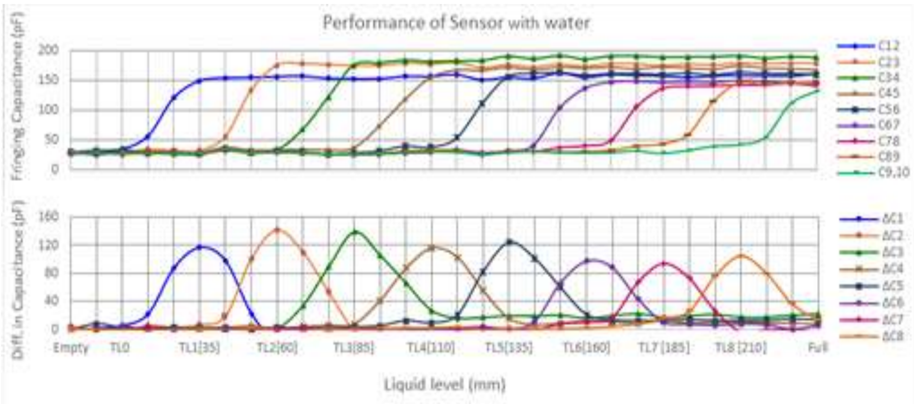


Figure 5: Characteristic curves of multi-threshold level sensor

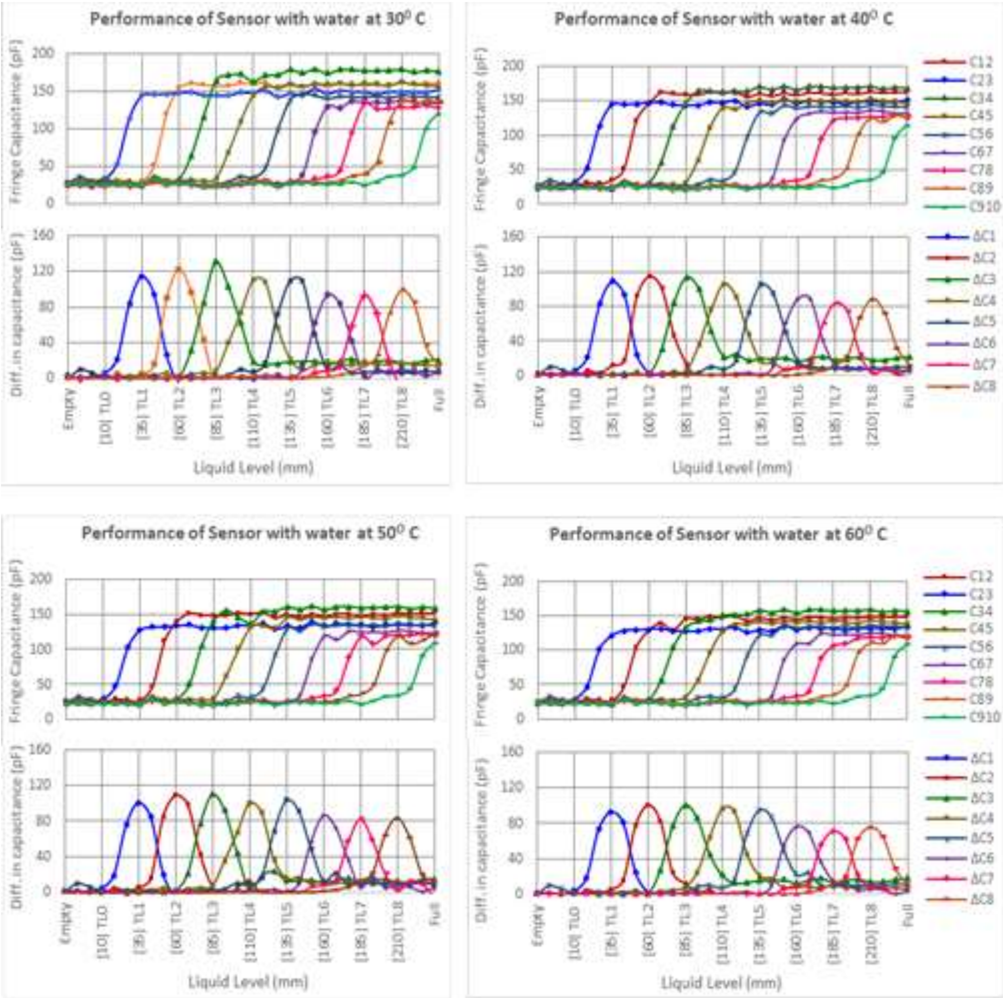


Figure 6: Characteristic curves of multi-threshold level sensor with water at different temperatures: (a)30°C, (b)40°C (c)50°C and (d)60°C

7. CONCLUSIONS

The main objective of this work is to develop fringe capacitance based multi- threshold level sensor to avoid the repetitive calibration, irrespective of the variation in dielectric constant of target liquid owing to the variation in process/environmental parameters. For the performance evaluation, variation in the temperature of water is considered in the experimental work. Initially, the response of multi threshold level sensor is examined by using water at room temperature. It is observed from the experimental work that all possible peaks, ΔC_1 to ΔC_8 occur at *instant when water level reaches the midpoint of the respective middle electrodes* (threshold levels) with an error of 0.816% FSO.. PLC-S200 has determined the existing threshold level by monitoring the occurrence of peak of the respective resultant ΔC curves.

Further, experimental work is carried out with water at different temperatures, 30°C, 40°C, 50°C and 60°C for the validation of self-calibration feature of the proposed sensor. It is confirmed from the results that the responses of sensor are similar irrespective of temperature of water. Also, all peaks, ΔC_1 to ΔC_8 occur at the threshold levels with lowest error varying from 0.408% FSO to 0.816% FSO. PLC-S200 identifies the occurrence of peaks and hence threshold levels, irrespective of their magnitude, irrespective of change in dielectric constant of water due to variation in its temperature. Consequently, the performance of the sensor remains same ensuring self-calibration

REFERENCES

[1] L. K. Baxter,1997, “Capacitive Sensors Design and Applications”, Wiley IEEE Press, New York, pp.i-xiv.

[2] Hidam Kumarjit Singh, Sumit Kumar Chakroborty, Hriday Talukdar, NungleppamMonoranjan Singh, TulshiBezboruah, “A New Non-Intrusive Optical Technique to Measure Transparent Liquid Level and Volume”, IEEE Sensors Journal , Vol.11, No. 2, pp.391 – 398, 2011.

[3] Hidam Kumarjit Singh, Nongthombam Chingkhei Meitei, Sashikanta Talukdar Sarkar, Dhanajay Tiwari, TulshiBezboruah, “Truly Nonintrusive Liquid-Level-Sensing Method Based on Lateral Displacement Effect of Light Rays”, IEEE Sensors Journal, Vol.13, No. 2, pp.801 – 806, 2013.

[4] Hui-Xin Zhang, Yu-Long Hou, Li-Shuang Feng, Shan Su, Jia-Wei Zhang, Jia Liu, Wen-Yi Liu, Jun Liu and Ji-Jun Xiong, “Polymer Optical Fiber Continuous Liquid Level Sensor for Dynamic measurement”, IEEE Sensors Journal, Vol.15, No. 9, pp.5238-5242, 2015.

[5] Tomasz Osuch, Tomasz Jurek, Konrad Markowski, and Kazimierz Jedrzejewski, “Simultaneous Measurement of Liquid Level and Temperature Using Tilted Fiber Bragg Grating”, IEEE Sensors Journal, Vol.16, No. 5, pp. 1205-1209, 2016.

[6] T.Vontz and V.Magori, “An ultrasonic flow meter for industrial applications using a helical sound path”, Proc. IEEE Symp. Ultrasonics, Vol.2, pp.1047–1050, 1996

[7] Somnath Mukherjee, PhinixLLC, “Non-invasive Measurement of Liquid Content inside a Small Vial”, IEEE Conference on Radio and Wireless Symposium (RWS), Neworleans, USA, pp. 527 – 530, 2010.

[8] T. Nakagawa, A. Hyodo, K. Kogo, H. Kurata, K. Osada, and S.Oho, “Contactless liquid-level measurement with frequency-modulated millimeter wave through opaque container”, IEEE Sensors Journal, Vol.13, No. 3, pp. 926–933, 2013.

[9] Satish Chandra Bera, Jayanta Kumar Ray, and Subrata Chattopadhyay, “A low-cost noncontact capacitance-type level transducer for a conducting liquid”, IEEE Transactions on Instrumentation and Measurement, Vol. 55, No. 3, pp. 778 – 786, June 2006.

[10] Sagarika PAL, Rasmiprava BARIK, “Design, Development and Testing of a Semi Cylindrical Capacitive Sensor for Liquid Level Measurement”, Sensors & Transducers Journal, Vol. 116, No. 5, pp. 13-20, 2010.

[11] S.Chakarborty, S. K. Bera, N. Mandal, and S.C. Bera, Studyon Further Modification of Non-Contact Capacitance type Level Transducer for a Conducting Liquid, IEEE Sensors Journal, vol. 15, no.11, pp.6678 – 6688, 2015.

[12] BaoquanJina, ZeyuZhangb, HongjuanZhangbaKey, “Structure design and performance analysis of a coaxial cylindrical capacitive sensor for liquid-level measurement”, Sensors and Actuators-A, 223, pp.84–90, 2013.

[13] Ferry N. Toth, Gerard C.M.Meijer and Matthijs van der Lee, "A Planar capacitive precision gauge for liquid-level and leakage detection", IEEE Transactions on Instrumentation and Measurement, Vol. 46, No. 2, pp. 644–646, Apr. 1997.

[14] K. Chetpattananondha, T. Tapoanoib, P. Phukpattaranonta, N. Jindapetch, "A self-calibration water level measurement using an interdigital capacitive sensor", Sensors and Actuators-A, 209, pp. 175–182, Jan. 2014.

[15] Cihun-Siyong Alex Gong, Huan Ke Chiu, Li Ren Huang, Cheng Hsun Lin, Zen Dar Hsu, and Po-Hsun Tu, "Low cost comb-electrode capacitive sensing device for liquid-level measurement", IEEE Sensors Journal, Vol. 16, No. 9, May 2016.

[16] Alexander V. Mamishev, Kishore Sundara-rajan, Fumin Yang, Yanqing Du and Markus zahn, “Interdigital Sensors and Transducers”, IEEE Proceedings, vol.92, no.5. 2004.

[17] Jaime Mizuguchi, Juliani Chico Piai, José Alexandre de França, Maria Bernadete de MoraisFrança, Karina Yamashita, and Luis Carlos Mathias, "Fringing field capacitive sensor for measuring soil water content: Design, manufacture, and testing", IEEE Transactions on Instrumentation and Measurement, Vol. 64, No. 1, pp. 212-220, Jan. 2015.

[18] Thomas Mohr, Uwe Ehrenberg and Hermann Uhlmann, “A new method for a self-calibrating capacitive sensor”, IEEE Instrumentation and Measuremeent Technology Conference, Vol.1, pp. 454-459, 2001.

[19] Suresh Babu C. S. and Premila Manohar, “Design of switching unit for fringe capacitance based smart sensor for multi threshold liquid level monitoring”, IEEE International Conference on Smart Sensors and Systems (IC-SSS-2015), MSRIT, Bangalore, India, 2015

[20] Suresh Babu C. S. and Premila Manohar, “Design of self-compensated non-contact type capacitive sensor for liquid level control with enhanced sensitivity-A novel approach”, Proc. Processing and fabrication of advanced materials (PFAM)-XXIII, IIT-Roorkee, India, Vol.1, No.1, pp. 580-588, 2014.

[21] Suresh Babu C. S. and Premila Manohar, “Design of a low cost signal conditioning circuit for self-compensated non-contact capacitive type multi threshold liquid level sensor”, IEEE International Conference on Circuits, Control, Communication and Computing (IC-4C), MSRIT, Bangalore, India, 2014.

[22] C. G. Malmberg and A. A. Maryott, “Dielectric Constant of Water from 0^0 to 100^0C ”, Journal of Research of the National Bureau of Standards Vol. 56, No. I, pp. 1-8, January 1956, Research Paper 2641.